DOCUMENT RESUME

ED 307 143 SE 050 599

AUTHOR Loving, Cathleen
TITLE Current Models in Philosophy of Science: Their Place in Science Teacher Education.
PUB DATE 89
NOTE 34p.; Paper presented at the Annual Meeting of the National Association for Research in Science Teaching (62nd, San Francisco, CA, March 30-April 1, 1989).
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *College Science; Educational Research; Epistemology; Higher Education; *Methods Courses; Methods Teachers; Philosophy; *Preservice Teacher Education; Science History; *Science Teachers; *Teacher Education; *Teacher Education Curriculum; Teacher Education Programs; Teacher Educators; Teacher Effectiveness

ABSTRACT

Many believe that whether teachers teach students to "do" science, teach about science, or teach about technology instead, science teachers should be as culturally literate about science as possible. Also, it is believed that a philosophy of science course which uses history of science, some normative epistemologies, practical examples, and current post-modernist views could promote that cultural literacy. The purpose of this study is to explore the need for a historically vibrant philosophy of science course; evaluate the current status of such programs; and offer an initial framework to science teacher educators for a course in philosophy of science. As a result of a literature search, a 17-institution survey, and a methods texts evaluation, important questions in philosophy of science have emerged which need to be included in science teacher education programs. The final contribution in this study is a framework which begins to address specific important issues such as the nature of theories, the quality of explanations, and how various confirmatory techniques differ. The paper describes purpose, methods, results, and methods text evaluation, as well as a model or framework for philosophically valid questions about science. Appendices include a questionnaire, a list of institutions surveyed, the text of the qualitative evaluation, and 44 references. (RT)

Current Models in Philosophy of Science: Their Place in Science Teacher Education

On the special way a teacher needs to view science:

"...he needs to take a view of science which is more that of a philosopher of science than of the professional scientist. This is because, like most professionals, the average scientist will need too much of his mind and energy concentrated on the practise of his science to allow him to be very reflective about what he is doing. The teacher will almost daily be confronted with questions from his pupils both about the value of what he is teaching, and about the particular 'rules' which it embodies which make it different from other school activities. From this it follows that the intellectual activity which will be required is not only that of his first degree discipline, but also will be that of participating in the impact and change of science in the world at large, which we have described as philosophical."

Shayer, M. & Adey, P (1981). Towards a science of science teaching.
London: Heinemann. p. 150.

Cathleen Loving
The University of Texas at Austin
NARST Annual Meeting
San Francisco
March 30, 1989

PURPOSE

The purpose of this study is to explore the need for a historically vibrant philosophy of science course for prospective science teachers as a way to improve their "cultural literacy" in various scientific disciplines; to evaluate the current status of such programs, both in terms of presence of such a dimension and degree of agreement with current philosophical models; and to offer an initial framework to science teacher educators for a course in philosophy of science.

While the controversy persists about whether to teach students to "do" science, about science, or, instead, about technology, and C.P. Snow's description of the gap between the culture of science and the rest of humanity is more appropriate than ever, one point of agreement should emerge. Science teachers, no matter what they end up teaching, should be as 'culturally literate' about science as possible to allow for the most immediate adaptation to changing curricular emphases. A philosophy of science course designed for science teachers that uses history of science, some normative epistemologies, current post-modernist views, and practical examples could promote that 'cultural literacy."

The problem of finding models of science that incorporate any inherent structures as well as those human dimensions that may be termed its "culture," and that are both descriptively accurate of how scientists do their work and yet normatively definable, is a real challenge. It is, however, necessary that those who educate others about science have some composite framework in mind while espousing the virtues of their scientific discipline. Current writings in both history and philosophy of science seem to support both (historical and philosophical) approaches as being vital to the complete view of the other--while each asks its own brand of questions. Presenting a balanced view combining the best of so-called formalist tenets, like those of Hempel and Salmon, with more relativist views, as Kuhn's or Toulmin's, together with historically accurate accounts of both modern and post-modern science, may bring a new vitality to a science teacher education program.

Many diverse thinkers have called for philosophy of science to be a component of teacher training (Abimola, 1983; Bridgham, 1969; Harms and Yager, 1981; Summers, 1982; Vitz, 1982), but this advice has gone largely unheeded (Hodson, 1988). Norris (1984) says that by having an accurate view of science, teachers and students will see that there is no claim of immunity from revision in science anywhere. He also thinks the knowledge of philosophy of science will aid in finding balance between dogmatism, cynicism, skepticism, and relativism in our presentation of science. Aikenhead's (1986) course for teachers supports the STS model to correct what he calls the unconscious bias against science, the scientist, and the role of science promoted in traditional science courses. He argues for it by combining historical case studies with current philosophical models. Richard A. Duschl (1985, 1986, 1988) has written extensively of the need to humanize science through history and philosophy.

There are a number of ways that researchers see this background in philosophy of science helping specifically in curriculum development. Calls for curriculum reorganization using modern philosophical models (Klopfer, 1969; Prather, 1987; Raths, 1973; Robinson, 1969) are common. In reviewing thirty-five major reports on the state of science education done since 1980, Hurd (1987) identified curriculum development as "the very stuff of education" (p. 19). The problem is not so much how science is taught but what is taught as science (Prather, 1987). In agreeing with other researchers, Hodson (1988) says it is the implicit, unplanned philosophy of science underpinning many curricula which ends up carrying the important message about the true nature of science. He calls for a more philosophically valid curriculum.

The extent to which current portrayals of science are philosophically in tune with so much that has been written in the last twenty years is a fundamental concern in this study. The literature is not very kind to science education. "There is probably no other subject whose teaching is so at odds with its nature" (Hurd, 1987, p.27 quoting from <u>First Lessons</u>). Even if teachers claim to have a more philosophically valid outlook, extensive observations reveal that most teachers are not able "to square their performance with their theory" (Goodlad, 1984, p. 214). Too often the process and product of science are regarded as being unproblematic (Bentley, et al 1985), leading to an authoritarian view which supports such ideas as equating creationism with evolutionary theory, "encouraging students to either ignore, accept on faith , or reject out of hand each new scientific finding" (Eldredge ,1981, p. 15). The excessive commitment to empiricism and induction among science educators does not square with modern science, and it promotes overuse of the "process approach," which can be equally unbalanced (Finley, 1983). Many of our colleagues still define science as "unrestrained inductive thinking," a "body of knowledge," a "systematic objective search." All of these arguments are only true some of the time in some of the sciences. Still others in science education who embrace the post-modernist views of Thomas Kuhn, Paul Feyerabend, and others may have lost a sense of balance--for their writings, which turned empiricist, inductivist science on its head in the 1960's and 70's, have undergone extensive scrutiny in the last ten years.

Many instruments have been devised to measure student and teacher views about the nature of science. The acronyms TOUS, WISP, COST, and NOSS represent some. Most of these are Likert-type or multiple choice tests, each based on a single interpretation of science, often with little or no input from the community of historians and philosophers of science, either through their writings or their participation. In fact, the lack of involving the community of historians and philosophers of science (many of whom are scientists first--like Kuhn, Holton, Salmon) is said to be one of the principal reasons the "alphabet" curricula promoted the little, weird-man-in-the-white-coat image of science, ignoring what historians, sociologists and philosophers were saying about the effects of the scientific "community" upon the activity of science (Duschl, 1985).

Some current philosophical disputes regarding the nature of science and how it should be presented in classrooms have penetrated the science education literature. One example (Willson, 1987 ; Norris, 1985,1987) deals with the extent to which observation is an objective, empiricist activity, free from bias--or theory-generating--versus the view that science is theory-laden or theory-driven. The notion that we "see" based on what we already know and have already seen is important in science and science education. Its debate spills over into disagreements about how to present observations to students of different ages and how to best view the novice-expert distinction. Where observation ends and inference begins and where the starting point for theory lies are dynamic topics ripe for inclusion in teacher education programs.

While some of the literature reveals innovative approaches to teaching about the nature of science (Aikenhead, 1986; Gray, 1986; Fiske, 1986), the occasions where students are being exposed to the culture of science through a philosophically valid course seem too rare. For this reason the following surveys and subsequent beginning framework were developed .

METHODS

First, an extensive, qualitative appraisal of the primary and secondary literature in both philosophy of science and science education was conducted to ascertain the value of a philosophy of science dimension in science teacher education and what questions might be pertinent to those teachers. Careful consideration was given to works from varying philosophy of science "schools."

This was followed by a survey of seventeen leading institutions, whose science education programs are known to have very active NARST members. The survey consisted of six questions regarding both the undergraduate and graduate programs in science education and the extent to which important questions in philosophy of science are addressed in those programs (see Appendix A). Since some commented that their science methods courses were the place for such questions to be addressed, this was followed by a qualitative evaluation of ten current methods texts, both secondary and elementary. Each was evaluated for evidence in the introductory chapters that the nature of scientific knowledge and the diversity of the enterprise of science were dealt with in a manner aligned with current thinking in philosophy of science.

As a result of the literature search, the seventeen-institution survey and the methods text evaluation, important questions in philosophy of science have emerged which need to be included in science teacher education programs. The final contribution in this study is a framework or model which begins to address specific important issues--such as the nature of theories, the quality of explanations, and how various confirmatory techniques differ--and which can serve as a guide for various topics in a philosophy of science course for teachers.

RESULTS -

Questionnaire (All seventeen institutions responded)

Answers to the first question reveal that 47% of the fifteen institutions responding never have a philosophy of science course in their degree plan for undergraduate science education majors and 6% of the sixteen graduate programs responding never do, while 13% of undergraduate and 19% of graduate programs always do (see Appendices A, B, and C). Other survey results about specific issues reveal a sparse or scattered commitment to any philosophical/historical perspective about science.

Forty-five percent of the nine institutions with undergraduate science education programs who at least sometimes include a philosophy of science course always explore the second question--how philosophers differ in their answers to questions such as "how theory free are observations?" Of the thirteen graduate programs responding to the second question, 77% explore these questions usually in methods or foundations classes.

Question three asks " Do students analyze curriculum materials/textbooks to determine the extent of a positivistic/formalist vs. relativistic/post-modernist view of science disciplines and their methods? In other words, is there opportunity to be objective about the authors' philosophy of science?" Of the fourteen who responded for undergraduate programs, 0% always do and 36% never do. Graduate students from the sixteen institutions responding always do this in 25% of the cases. Those commenting said it was a good idea, it depends on the instructor, or that it is covered to some degree in methods courses. One response indicates that one-fourth of a methods course is devoted to the role of theories and the nature of scientific reasoning.

"Do students have an opportunity to look at the structure of their particular discipline based on not only what textbooks and science courses have said but also on what philosophers of science have added to the perspective?" is question four. For the thirteen undergraduate programs responding, 39% always do, and 23% never have this opportunity. Of the sixteen graduate programs responding, 56% always have this opportunity and 6% never do. Comments include the fact that this is very important; that it is a component in the secondary and elementary methods courses, though not in depth; and that it is viewed as meaningless without history of science--in fact one respondent sees history of science as separate and preferrable to philosophy of science.

Question five asks, "Do students have an opportunity to explore the question, "Where do you stand in defining science as a search for Truth vs. what works best?" Without much comment except one exclamation that "I haven't considered it!" and another that students do read sets of papers showing these instrumentalist-realist debates, results show 29% of the fourteen undergraduate programs responding always do this and 28% never do. Graduate programs always explore this question in 53% of the fifteen institutions responding, with 20% never exploring this question.

The final question is, "Do students have an opportunity to compare the ways that the structure and culture of science have been and are being described in the science education community, the scientific community, and the philosophy of science community?" A variety of interesting comments include belief that it is done through an STS component in the methods course; that students compare the science education community with philosophy of science, but that little is done on how scientists view it; one claims to teach a course heavy on epistemological issues as they relate to science teaching; that philososphy in all its aspects is handled in an incidental fashion in science courses; and finally that the respondent is aware of such a gap, but money and time make solving the problem difficult. All together, out of the twelve who responded for undergraduates, only 25% said they always dealt with this issue and 17% never do. For graduate programs, 43% always do these comparisons in courses and 7% never do.

Methods Text Evaluation

The methods text evaluation reveals only one text (#3) out of ten having a reasonably adequate treatment of the nature of science, assuming, as comments on the questionnaire suggest, that the methods course is where such things are discussed (see Appendix D). Others simply do not say enough or have incomplete or inaccurate views in light of modern philosophy and history of science.

Model or Framework for Philosophically Valid Questions About Science

While a first glance at the literature suggests that it would be difficult to provide a composite view of science that makes use of the many diverse "formalist" and "relativist" positions, there are a number of studies that make this possible. Recent writings of Holton (1986), Bernstein (1983), Salmon (1984), and Giere (1988) are examples which have helped bring together ideas first highlighted by such diverse thinkers as Sir Karl Popper and Thomas Kuhn. While the important questions which emerge from these and other readings and which ought to be addressed in a successful course on the nature of science are numerous, one topic which ties so many writings together involves the nature of scientific theories. Such controversies as whether real revolutions occur in science, whether discernible progress occurs, whether history can be used to learn to do a better job in science, and other dynamic questions are important to consider if one is to study the structure of science. But all of these seem to revolve around the understanding of scientific theories.

A course for science teachers should involve the reading of primary philosophical and historical works, evaluating everyday reports of scientific happenings in journals and newspapers, meeting with historians, philosophers, and sociologists of science as well as with scientists from different disciplines in various panel discussions. But the immediate interest in the planning of such a course is in the development of a model which would help science teachers visualize the dynamic structure of science (in this case the views on theories) in terms of the many experts who focus on the act of trying to interpret science.

One way to get a sense of the varied notions of the structure of science from the experts is to compare the writings of philosophers, historians and sociologists of science on how theories should be evaluated and whether the resulting best explanations represent the truth or are mere models and instruments. This tends to align interpreters of science into different "camps," or at least they are often given labels. One is a realist (explanations represent aspects of the real world) or an anti-realist (theories are accepted for problem-solving effectiveness); one is a rationalist (there are principles for the evaluation of theories) or a naturalist (theories come to be accepted through a natural process of both individual judgment and social interaction). Ronald Giere (1988, p. 8), whose cognitive theory of science is represented by the realist, natural quadrant below has provided this author with one model which, when modified, might prove valuable for science teacher education.

REPRESENTATION

JUDGMENT	realist	anti-realist
rational		
natural		

The development of an alternative framework is underway. Believing that labels are often inaccurate (liberal and conservative, for example) and using the notion of a continuum or spectrum of views--that is, making the assumption that one's position in the rationalism vs. naturalism or realism vs. anti-realism debate will be in degrees rather than mutually exclusive divisions--this could be used to explain to future science teachers how those who interpret science differ on the structure of science and, eventually, how the science teachers might judge their own views of science against the experts. The current philosophers of science (and a few historians and sociologists), whose work is being examined are Sir Karl Popper, Thomas Kuhn, Imre Lakatos, Larry Laudan, Gary Gutting, R.J. Bernstein, Stephen Toulmin, Gerald Holton, Carl Hempel, Wesley Salmon, Clark Glymour, George Kneller, I. Bernard Cohen, Dudley Shapere, Ronald Giere, whose structure of science quadrant is being adapted, and a few sociologists of science, R.K. Merton and his disciples, for example, who tend to define science as being understood largely by factors outside itself.

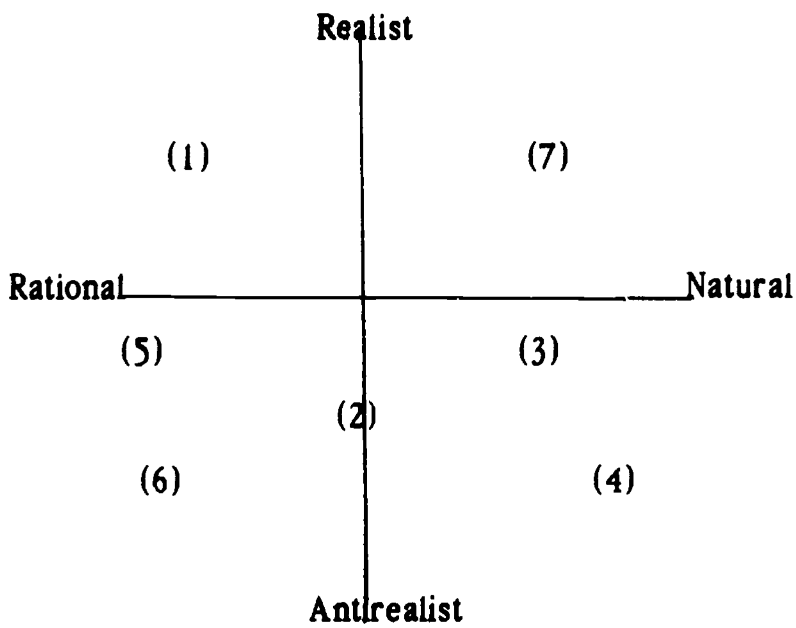
The altered framework borrows from the idea of a coordinate system with an x- and y-axis and from David A. Kolb's Learning Style Profile and Grid (Kolb, 1976). In this instrument one's learning style is plotted on a grid based on four attributes of experiential learning: concrete experience, abstract conceptualization, reflective observation and active experimentation. The degree of abstractness over concreteness is plotted against the emphasis on active experimentation over reflection. In a similar fashion, views of scientific theories as representing reality (realist) versus being models for problem-solving (anti-realist or instrumentalist) can be plotted against belief in rational methods for evaluating theories versus natural ones. Attempting to plot known experts' views with the help of specific criteria for each extreme on the coordinate system helps to identify trends in thinking, evaluate extreme views or moderate ones, and at the same time, helps give a more global view of what a definition of science might entail.

This particular framework addresses two important questions about science: how are theories evaluated (judgment) and how are they viewed in terms of the real world (representation). Other specific frameworks can be developed to address other aspects of science. For example, there are different criteria involved in decisions about how theories are invented--and the extent to which they evolve from old theories, pure intuition, prior knowledge and hard data, strong presuppositions, etc. Some philosophers who have written a great deal about the evaluation of theories have done little in the area of invention of theories--so they might not have given adequate attention to the question and would not be included in both frameworks.

The important point is that these frameworks can serve as models to aid in understanding what the components of the structure of science are and how current thinkers view this structure. They could aid in the development of a theory of science for science teachers. To avoid the danger of oversimplifying one's position on the continuum, detailed descriptions and examples for each quadrant will be necessary. The preliminary framework gives only a general indication of position and looks like this:

Views on Theory Judgment and Representation

x-axis = judgment(theory s value); **y-axis** = representation (theory's truth)



A brief description of some of the philosophers and their tentative grid placement follows:

(1) Sir Karl Popper (1982, 1983), perhaps the most prolific (almost fifty years of publishing) and highly respected philosopher of science in the 20th century, is best known for his belief in "conjectures and refutations." He, like most philosophers of science, lines up in the rationalist column, believing that reason, logic and critical judgment all best explain how theories are evaluated. He is a realist, believing that the best explanations are reductions of existing theories--what he sees as an identificaiton of the unknown with the known. Where he differs from most is in his vigorous insistence that scientists should engage in making bold, speculative theories and then try to determine their fallibility, using the most critical approaches possible. He believes in tests as attempted refutations, knowledge as always remaining fallible and conjectural, and good science as the elimination of errors (1983, pp. xix-xxxix). His view that theories are not confirmable, but are only able to be refuted is well known. He sees the best theories as those with the greatest explanatory power, greater content, and greater testability as coming closer to the truth than lesser theories--thus his realist position on the grid. (He is actually closer to the middle of the grid than he would be with his earlier writings, when he tried to define truth in terms of "verisimillitude," that is, different phenomena and their explanations as varying approximations of the truth. He later abandoned this absolutist position.

(2) Thomas Kuhn, a physicist and a historian of science, whose views are well known today (1970a, 1970b, 1982) stands apart and distinct from

Popper. While there is always going to be disagreement as to particular placements on such a grid, Kuhn perhaps belongs somewhere along the y-axis, as his brand of rationality is quite practical (some would argue it belongs in a "natural" quadrant) and is based on what he calls "concrete exemplars," which exist within particular scientific communities or traditions--often called paradigms. But after numerous critics wrote of the term's inaccurate or multiple applications--Marjorie Masterson (1970) pointed out over twenty different ways it was used in The Structure of Scientific Revolutions-- he essentially abandoned the term. His brand of truth is limited to the best explanations that develop in a particular community at a particular time in history. Thus, the notion that we are closer to the "truth," in any global sense, today than say in the 19th century would disturb Kuhn. Thus he is an anti-realist to some degree.

(3) Paul Feyerabend (1975), once referred to as the "enfant terrible," writes that evaluation of theories is essentially an irrational endeavor, so heavily weighted by social factors and the lack of real method that it is relatively easy to place him somewhere in a natural quadrant. Furthermore, his views are so relativistic compared to others, that truth isn't a real consideration in the representation of scientific explanations.

(4) Most current sociologists of science fall into a naturalist, anti-realist quadrant, since their work so heavily depends on defining science first as a social system. A few examples deal with such things as gift giving as an organizing principle of science (Hagstrom, 1982), the fear of innovation (Schon, 1982), scientific autonomy and politics (Jagtenberg, 1983) and so on. For the time being, they will be lumped together in the anti-realist, natural quadrant. They deserve more detailed analysis.

(5) Both Imre Lakatos (1970) and (6) Larry Laudan (1977, 1984) believe science to be historically developmental like Kuhn--with Laudan being more of an anti-realist than Lakatos, whose most noteworthy contribution to our understanding may be the emphasis on the nature of the research program rather than the ascent of a relevent community. They both differ from Kuhn in their views of science as making rational progress rather than a more natural development, although Lakatos is closer to Karl Popper in his embracing rationalism--through the use of auxiliary hypotheses to guarantee possible confirmation of theories rather than Popper's insistence that confirmation is essentially impossible.

(7) Ronald Giere (1988) is developing a cognitive theory of science which emphasizes more the structure of science than its development, as Kuhn does. Rather than focusing on the standards of the relevent community of scientists, he focuses on the cognitive processes of all scientists, from the internal neuroscientific exchanges involved in judgment and representation to their manifestation in cognitive maps, certain geometric patterns which seem easy to "picture," and complex schemata which may explain much about resulting explanations. His original table which has been modified for this study places him in an as yet rather undeveloped quadrant of realist and naturalist. The scientific "truth" emerges from "human activities .... as entirely natural phenomena, as are the activities of chemicals or animals." And since the cognitive sciences have been so empirically successful lately, the long tradition of "using science in the attempt to understand science itself" is more attractive than ever (p. 8).

DISCUSSION

From the results of the questionnaire, the methods text evaluation, and the literature search it appears that there is a good chance that a new science teacher, an experienced teacher going back for graduate work, or a science education professor/researcher with a doctorate will have little background in some important questions in philosophy of science. There are bright spots in some of the seventeen institutions surveyed and in one or two of the methods texts evaluated. Overall, little evidence exists that much is being done other than incidental inclusion in some methods course or leaving it up to the student if, as one respondent put it, "At times we get a student or two with this type of interest and they pursue the study which you mention." Philosophy of science does not appear to be viewed by many science educators as a necessary component to the education of science teachers--at least not yet.

The literature, the questionnaire and the methods text evaluation all reveal a lack of a philosophically valid approach to understanding science for science teachers. One way to begin achieving this is through a course which allows those teachers to explore the variety of approaches that currently exist for explaining what scientists do when they do it well. By learning where various experts with diverse perspectives stand on key aspects of the structure of science, these teachers may be forced to examine their own positions.

It is hoped that the suggested framework could eventually be used for self-evaluation, like Kolb's grid. As specific criteria are further refined within each quadrant, it may be possible to develop a scoring system similar to Kolb's. One way to quantify and make more precise the indicators for each segment of the framework is to test large numbers of experts and get the norms for that group. Future work comparing the public with the experts, or scientists with philosophers of science, seems to have merit, as we all stuggle to have a better match between what is taught as science and what it really is--or is perceived to be.

As this framework develops in detail, and as it is later used with future or current science teachers, the hope is that their understanding of what science tries to do and what good scientific theories are will become deeper, more profound--and their responses to student inquiries in the future more philosophical, in the sense of having a broader perspective on what are too often cut and dry responses. Current debates about such topics as whether creation "science" should be taught alongside evolutionary theory could be vastly clarified if a deeper understanding of scientific theories were held by more people--especially science teachers.

Questionnaire

I am interested in determining to what extent those preparing to be science teachers (K-12) and/or working on advanced degrees in science education in your institution have coursework that addresses these or similar questions. (While history of science is integral to a good philosophy of science course, my focus is exclusively on how philosophy of science is addressed, not history of science).

1. Do students have a **philosophy of science** course in their degree plan?

Undergraduate

Always____
Sometimes____
Never____

Graduate

Always____
Sometimes____
Never____

Comments:

2. If yes, do students explore how philosophers of science **differ in their interpretations** of such questions as "what is science?" "how theory-free are observations?" "are rival theories really incommensurable?" (as opposed to being taught the answers to such questions based on the professor's own philosophy).

Undergraduate

Always____
Sometimes____
Never____

Graduate

Always____
Sometimes____
Never____

Comments:

3. Do students analyze curriculum materials/textbooks to determine the extent of a positivistic, formalist vs. relativistic, post-modernist view of science disciplines and their methods? In other words, is there opportunity to be objective about the author's philosophy of science?

Undergraduate

Always_____
Sometimes_____
Never_____

Graduate

Always_____
Sometimes_____
Never_____

Comments:

4. Do students have an opportunity to look at the structure of their particular scientific discipline based not only on what textbooks and science courses have said but also on what philosophers of science have added to the perspective?

Undergraduate

Always_____
Sometimes_____
Never_____

Graduate

Always_____
Sometimes_____
Never_____

Comments:

5. Do students have an opportunity to explore the question, "Where do you stand in defining science as a search for Truth vs. 'what works best'?"

Undergraduate

Always_____
Sometimes_____
Never_____

Graduate

Always_____
Sometimes_____
Never_____

Comments:

6. Do students have an opportunity to compare the ways that the structure and culture of science have been and are being described in the science education community, the scientific community, and the philosophy of science community?

Undergraduate

Always_____
Sometimes_____
Never_____

Graduate

Always_____
Sometimes_____
Never_____

Comments:

Appendix B

Institutions Surveyed on Extent of Philosophy of Science in Undergraduate and Graduate Science Education Programs

1. Arizona State University (Dr. Anton Lawson, Department of Biology)

2. Columbia University/NY (Dr. O. Roger Anderson, Teacher's College)

3. Cornell University/NY (Dr. Joseph Novak, Department of Education and College of Agriculture and Life Science)

4. Hunter College, City University of New York (Dr. Richard Duschl, Department of Curriculum and Teaching)

5. Indiana University (Dr. Hans Anderson, Department of Education)

6. Ohio State University (Dr. Patricia Blossner, Department of Science Education)

7. Pennsylvania State University (Dr. Robert Shrigley, Division of Curriculum and Instruction)

8. Rollins College/FLA (Dr. Linda Deture, Department of Education/Human Development)

9. Texas A&M University (Dr. Robert K. James, Center for Science and Mathematics)

10. University of California at Berkeley (Dr. Marcia Linn, Lawrence Hall of Science)

11. University of Georgia (Dr. Russell Yeany, Department of Science Education)

12. University of Iowa (Dr. George Cossman, Department of Science Education)

13. University of Maryland (Dr. William Holliday, Science Teaching Center)

14. University of Oklahoma (Dr. Edmund A. Marek, Science Education Center)

15. University of Pittsburgh/PA (Dr. Willard Korth, Department of Instruction and Learning)

16. University of Texas at Austin (Dr. James Barufaldi, Science Education Center)

17. Utah State University (Dr. Donald Daugs, Department of Science Education)

Appendix C

Table C-1

Extent of Incorporating Philosophy of Science in Science Education Programs

Undergraduate Programs

Question	1 (15)	2 (9)	3 (14)	4 (13)	5 (14)	6 (12)
	%	%	%	%	%	%
Always	13	45	0	38.5	28.5	25
Sometimes	40	33	64	38.5	43	58
Never	47	22	36	23	28.5	17

Graduate Programs

Question	1 (16)	2 (13)	3 (16)	4 (16)	5 (15)	6 (14)
	%	%	%	%	%	%
Always	19	77	25	56	53	43
Sometimes	75	23	69	38	27	50
Never	6	0	6	6	20	7

Note: Number of responses in parentheses

APPENDIX D

Methods Text - Qualitative Evaluation of an Adequate Treatment of Nature of the Scientific Enterprise

Ten current methods texts in science education were evaluated. Five focused on elementary education, one on both elementary and junior high school, two were described as being for middle and secondary school and two were for secondary science teachers. The publication dates ranged from 1981 to 1987. For each text, evidence was sought in the introductory chapters that the nature of scientific knowledge and the diversity of the enterprise of science were at least dealt with, rather than the introduction being limited to a description of all science as having content, processes, and attitudes--and that is it. The texts were assigned numbers according to an alphabetical listing of the authors. Their identity remains anonymous. Although a strict numerical ranking did not occur, since quantitative evaluation did not take place, they are discussed below more or less beginning with those with little or no reference to the nature of science and ending with one in particular that has a fairly strong philosophical component, interpreting science rather extensively.

Text #5 is for elementary teachers and it defines science in a very traditional way--"body of knowledge," "set of processes and attitutdes." There is no inkling that there might be differences between the disciplines, other than content, or between the scientists themselves.

Text #4 totally integrates content and process for the elementary teacher right away. There is no background on the nature of science at all, and the text goes right into how to teach concepts through process, without any evidence of the developmental nature of that knowledge. If the children were to ask, "How did they know this or when?" the teacher would be at a loss if he or she depended on this book.

Text # 7 stresses the need for elementary and junior high school teachers to have a "comprehensive overview of modern science" and it promotes variety in the ways to teach it. But there is nothing in this book on the developmental nature of science, and no mention of the lengthly ways the information is obtained. It is full of content, but how it is that scientists come to know such knowledge is totally missing.

Text #10 is for elementary teachers, and the author generalizes a great deal when referring to science as "systematic, methodical work" and scientists as ones who all "suspend judgment until the facts are in." There is no mention of varying philosophies and no distinction in the methods for the varying disciplines. It uses educational research as its example of use of the scientific method.

About the only reference to variety in scientific interpretation in **Text #1** (for elementary teachers) occurs when the author refers to observation and seeking truth as being like the three blind men and the elephant. One felt the texture, width and length and "saw" a tree. The second felt the trunk and "saw" a serpent. The third felt the rear.

Text #2 is for secondary teachers and has a good emphasis on the humaneness of science in the introduction but no mention of varying philosophies on its nature. "Scientists thus succeed in the long run because of their daily, intelligent failures, and we can follow this example in our own everyday attempts to solve problems of living, teaching, human relations and so forth...the knowledge that the only certainty in scientific work is uncertainty and change" (p.8)

Text #6 stresses the basic processes of science and operational definitions. It equates what students do in the classroom with real science. The author uses an interesting model to describe science, with assumptions forming the base, vertical beams built on that forming the generalizations and horizontal beams on top representing methods and processes. Revolutionary ideas are viewed as changing the vertical beams--the generalizations. No mention is made of changing assumptions! The model clearly suggests the cumulative nature of science. The author cites Thomas Kuhn in a chapter on the nature of science, in reference to revolutionary ideas, but Kuhn's writings do not agree with this model. The term "prediction" is described as a guess rather than a powerful tool used with sound theory, as most experts describe it.

As is the case with a number of these texts, **#8** makes a beginning at describing the scientific enterprise, but it ends up with a list of what we need to know about scientific knowledge in order to be literate--that it is tentative, public, replicable, probabilistic, humanistic, historic, unique, holistic, and empirical. None of these points about science is developed. Twenty-nine key concepts in science from cause and effect to validation are considered crucial to scientific literacy. Other examples are theory and model, but missing are observation and prediction, which apparently are viewed as simple processes instead of carefully explicated concepts.

The authors of **text #9** definitely stress the different models of inquiry and mention a lot of names associated with those models: Descartes, Bacon, Hume, Locke, Berkeley, Ayer, Polyani, Bronowski, Kuhn, and Popper. They criticize Baconian induction and logical positivism, but this is not well developed. It seems too chopped up. Each model needs explanation. There is just too little of a good thing. There are many beginnings here, but lack of development occurs.

In relation to all the others, **text # 3** stands far and away the best philosophical treatment of scie:..e for pre-service science teachers. It is relatively balanced, comprehensive and well written. First of all, the bibliography is excellent, showing thorough research into some of the philosophical questions. The authors cite Carey and Stauss's 1968 and 1970 studies showing that science teachers do not understand the nature of science. They devote a whole chapter--23 pages--to the topic "The Scientific Enterprise and Science Teaching." They mention that "We cannot expect our students to understand the laws, concepts, principles, and theories of science without their first having an understanding of how they were derived." Philosophy is mentioned as a legitimate and important way to look at science. The limits to observational error are acknowledged. Tentativeness of both hypotheses and theories is synonymous with the enterprise, according to the authors. There is a good discussion of the difference between facts, hypotheses and theories and the difference between tenuous theories and those with great predictive power. There is at least a start of a discussion about the dy: :mic ups and downs, successes and failures, c :stant reorientation in real science versus what textbooks or history of science books often suggest. They say we ought to get a truer picture of science by reviewing journals with articles, rebuttals, new theories, letters of condemnation etc., and they add this dynamic nature is important to the citizenry. They take a Popperian view that hypotheses cannot be proven but only disproven. There is good discussion on various uses of the "method," and they stress the difficult nature of the "why" questions.

There are still more pluses in this chapter. There is an excellent section on fighting one's bias by recognizing its presence and by documenting studies to assure as much objectivity as possible. They talk about how changes in underlying assumptions force restructuring of science. A good discussion of induction and deduction follows, with the authors describing them as equally valuable. They say most theories are arrived at inductively but that models are arrived at deductively from theory. Here they could have done more to show historical examples. They go on to discuss cause and effect, and cite Hume, Russell, and others on the difficulty of attributing cause; they point out the difficulty with reductionists, like molecular biologists, who have "broken open the black box" and compositionists who say once this unit is broken open one cannot attribute cause and effect to parts. Finally, there is a good discussion of the difference between evidence and proof and of the problems that exist with the meaning and importance of scientific explanations--both causal and teleological.

References

Abimola, I. (1983). The relevance of the "new" philosophy of science for the science curriculum. School Science and Mathematics, 83(3), 181.

Aikenhead, G.D. (1986). Preparing undergraduate science teachers in S/T/S: A course in epistemology and sociology of science. Science Technology and Society: Resources for Science Educators (1985 AETS Yearbook). Columbus: Association for the Education of Teachers in Science and SMEAC Ohio State University, pp. 56-64.

Bentley, D.; Ellington, K.; & Stewart, D. (1985). Where are we going? An examination of some Secondary Science Curriculum Review philosophies of science education. Secondary School Review, June, 658-668.

Bernstein, R.J. (1983). Beyond objectivism and relativism: Science, hermeneutics, and praxis. Philadelphia: The University of Pennsylvania Press.

Bridgham, R.C. (1969). Conceptions of science and learning science. School Review, 78, 25-40.

Duschl, R.A. (1985). Science education and philosophy of science: Twenty-five years of mutually exclusive development. School Science and Mathematics, 85, 541-555.

Duschl, R.A. (1986). Developing reflective attributes in science teachers through the history of science. In R.K. James (Ed.) Science, technology and society: Resources for science educators (1985 AETS yearbook). Columbus: AETS and SMEAC Information Reference Center, pp.16-22.

Duschl, R.A. (1988). Abandoning the scientistic legacy of science education Science Education, 72(1), 51-62.

Eldredge, N. (1981). Creationism isn't science. The New Republic, 20, 15-17.

Feyerabend, P. (1975). Against method: Outline of an anarchistic theory of knowledge. London: NLB.

Finley, F.N. (1983). Scientific progress. Journal of Research in Science Teaching, 20(1). 47-54.

Fiske, E.B. (1986). Searching for the key to scientific literacy. New York Times Education Supplement 20-23.

Giere, R. (1988). Explaining science: A cognitive approach. Chicago: The University of Chicago Press.

Goodlad, J.I. (1984). A place called school: Prospects for the future. New York: McGraw-Hill.

Gray, P.E. (1986). MIT's study of its undergraduate program: Preparing students for the new millennium. The Chronicle of Higher Education (Dec.3).

Hagstrom, W.O. (1982). Gift giving as an organizing principle in science. In B. Barnes & D. Edge (Eds.) Science in context: Readings in the sociology of science. Cambridge: MIT Press.

Harms, N.C. & Yager, R.E. (Eds) (1981). What research says to the science teacher Vol 3, Washington, D.C.: National Science Teachers Association. pp.5-107.

Hodson, D. (1988). Toward a philosophically more valid science curriculum. Science Education. 72(1), 19-40.

Holton, G. (1986). The advancement of science and its burden: The Jefferson lecture and other essays. Cambridge, England: Cambridge University Press.

Hurd, P.D. (1987). Recommendations of national reports for the reform of American education: Elementary school science.

Jagtenburg, T. (1983). The social construction of science. Dordrecht, Holland: D. Reidel Publishing Company, pp.52-55.

Klopfer, L. (1969). TOUS. Science Education, 53(2), 155-164.

Kolb, D.A. (1976). The learning style inventory technical manual. Boston: McBer and Company.

Kuhn, T. (1970a). Reflections on my critics. In I. Lakatos and A. Musgrave (Eds.), Criticism and the growth of knowledge . Cambridge, England: Cambridge University Press. pp. 231-278

Kuhn, T. (1970b). The structure of scientific revolutions,2nd edition. Chicago: The University of Chicago Press.

Kuhn, T. (1974). Second thoughts on paradigms. In F. Suppe (Ed.) The structure of scientific theories. Urbana: University of Illinois Press, pp.459-517.

Kuhn, T. (1982). Normal measurement and reasonable agreement. In B. Barnes & D. Edge (Eds.). Science in context. Cambridge, Massachusetts : MIT Press, pp.75-93.

Lakatos, I (1970). Falsification and the methodology of scientific research programmes. In I. Lakatos & A. Musgrave (Eds.), Criticism and the growth of knowledge. Cambridge, England: Cambridge University Press, pp.91-196.

Laudan, L. (1977). Progress and its problems . Berkeley: University of California Press.

Laudan, L. (1984). Science and values. Berkeley: University of California Press.

Masterson, M. (1970). The nature of a paradigm. In I. Lakatos & A. Musgrave (Eds.), Criticism and the growth of knowledge. Cambridge, England: Cambridge University Press, pp.59-89.

Norris, S.P. (1984). Cynicism, dogmatism, relativism, and skepticism: Can all these be avoided? School Science and Mathematics, 84(6), 484-495.

Norris, S.P. (1985). The philosophical basis of observation in science and science education. Journal of Research in Science Teaching. 22, 817-833.

Norris, S.P. (1987). The roles of observation in science : A response to Willson. Journal of Research in Science Teaching, 24(8), 773-780.

Popper, K. R. (1982). The open universe. Totowa, NJ: Rowman and Littlefield.

Popper, K. R. (1983). Realism and the aim of science. Totowa, NJ: Rowman and Littlefield.

Prather, J.P. (1987). Analysis of the educational implications of the concept of scientific revolutions. Presented at the Annual Meeting of the National Association for Research in Science Teaching, April 25-27, Washington D.C.

Raths, J. (1973). The emperor's clothes phenomenon in science education. Journal of Research in Science Teaching, 10(3), 201-211.

Robinson, J.T. (1969). Philosophy of science: Implications for teacher education. Journal of Research in Science Teaching, 6, 99-104.

Salmon, W (1984). Scientific explanations and the causal structure of the world. Princeton: Princeton University Press.

Schon, D. (1982). The fear of innovation. In B. Barnes & D. Edge (Eds.) Science in context. Cambridge, Massachusetts: MIT Press.

Summers, M. K. (1982). Philosophy of science in the science teacher education program. European Journal of Science Education, 4, 19-28.

Vitz, E.W. (1982). Theory and exemplar: What can science philosophers tell science teachers about science? Journal of Chemical Education, 59(4), 298.

Willson, V.L. (1987). Theory-building and theory confirming observation in science and science education. Journal of Research in Science Teaching, 24(3), 279-284.